BROOKHAVEN NATIONAL LABORATORY
LASER CONTROLLED AREA
STANDARD OPERATING PROCEDURE (SOP)

This document defines the safety management program for the laser system listed below. All American National Standard Institute (ANSI) Hazard Class 3b and 4 laser systems must be documented, reviewed, and approved through use of this form. Each system must be reviewed annually.

System description: A fiber-coupled diode laser operating at 980 nm is used to partially neutralize an H- beam for beam diagnostics purposes. The work which will be done in the 750 keV portion of the linac is aligning the laser beam, testing the optics, and making measurements on the beamline in the BNL linear accelerator.

Equipment development will be performed in Room 103 of Building 930. This room is fully laser-interlocked. The interlock is described in Engineering Controls. Only qualified laser operators with proper safety equipment will be permitted inside the lab when the laser is operated.

Location: Building 930. The low energy line of the linac in the experiment box downstream from the Radio Frequency Quadrupole (RFQ).

LINE MANAGEMENT RESPONSIBILITIES

The Owner/Operator for this laser is listed below. The Owner/Operator is the Line Manager of the system and must ensure that work with this laser conforms to the guidance outlined in this form.

Owner/Operator:

Name: Roger Connolly *Signature:* ***Signature on File*** *Date:*

AUTHORIZATION

Work with all ANSI Class 3b and 4 laser systems must be planned and documented with this form. Laser system operators must understand and conform to the guidelines contained in this document. This form must be completed, reviewed, and approved before laser operations begin. The following signatures are required.

Chris Weilandics	***Signature on File***	
BNL LSO printed name	*Signature*	*Date*
Asher Etkin	***Signature on File***	
Department ES&H Approval printed name	*Signature*	*Date*

APPLICABLE LASER OPERATIONS
Operation Maintenance Service X Specific Operation X Fiber Optics

LASER SYSTEM HAZARD ANALYSIS

Hazard analysis requires information about the laser system characteristics and the configuration of the beam distribution system. The analysis includes both laser (light) and non-laser hazards. A Nominal Hazard Zone (NHZ) analysis must be completed to aid in the identification of appropriate controls.

LASER SYSTEM CHARACTERISTICS					
Laser Type *(Argon, CO_2, etc.)*	Wavelengths	ANSI Class	Maximum Power or Energy/Pulse	Pulse Length	Repetition Rate
Diode	980 nm	IV	2.65 W	NA	CW

☐ **Cryogen Use**

Describe type, quantity, and use.

None

☐ **Chemicals & Compressed Gasses**

Describe type, quantity, and use.

None

☐ **Electrical Hazards**

Description *(Describe the power supply to the system).*

None

☐ **Other Special Equipment**

Description *(Equipment used with the laser[s]).*

None

Laser System Configuration: Describe the system controls *(keys, switch panels, computer controls),* beam path, and optics *(provide a functional/block diagram for complicated beam paths)*.

The laser will be operated in two locations. Equipment development will be done in Room 103 of Building 930 (BNL linac). The door to this room has been interlocked to C-A department standards and the interlocks have been tested. Once the door is closed the interlock is set which enables the laser through the built-in interlock. Operationally this is done by electrically connecting pins 1 and 2 on connector DB-9. If the door to the room is opened the laser interlock latches off. The laser can be re-enabled by restoring the room to a safe condition and reseting the interlock.

Room 103 is an external room so reflection from the windows is a concern. We have installed a movable room divider at the end of the laser bench such that the divider subtends a solid angle sufficient to block any optical path from the bench to the window. The laser will only be operated from a location on this bench.

Safety equipment in this room includes three pairs of Kentek SES-01-BW safety goggles and two wavelength conversion wands which convert the invisible IR laser light into green light which is visible through the goggles. The manufacturer has supplied the following information about these goggles. Only fully-qualifiied BNL laser operators will be permitted in the laser lab during beam operations.

Interlock test procedure CA – OPM 4.120.?

KENTEK

Optical Densities for KG*L-01, KG*L-05

Wavelength (nm)	OD	Wavelength (nm)	OD	Wavelength (nm)	OD	Wavelength (nm)	OD	Wavelength (nm)	OD
200	8+	710	0.6	1220	7.2	1720	4.6	2230	3.6
210	8+	720	0.7	1230	7.2	1730	4.6	2240	3.6
220	8+	730	0.8	1240	7.2	1740	4.5	2250	3.8
230	8+	740	0.9	1250	7.1	1750	4.5	2260	4
240	8+	750	1	1260	7.3	1760	4.4	2270	4
250	8+	760	1.1	1270	6.8	1770	4.5	2280	4.1
260	8+	770	1.3	1280	7.1	1780	4.4	2290	4.2
270	6.3	780	1.4	1290	7.1	1790	4.4	2300	4.2
280	4	790	1.6	1300	7.1	1800	4.4	2310	4.2
290	2.4	800	1.7	1310	7.1	1810	4.4	2320	4.2
300	1.5	810	1.9	1320	7.1	1820	4.4	2330	4.2
310	0.8	820	2.1	1330	7.1	1830	4.4	2340	4.1
320	0.3	830	2.3	1340	6.9	1840	4.3	2350	4.1
330	0.2	840	2.5	1350	6.8	1850	4.3	2360	4.1
340	0.1	850	2.6	1360	6.9	1860	4.3	2370	4
350	0.1	860	2.8	1370	6.8	1870	4.3	2380	4
360	0.06	870	3	1380	6.4	1880	4.3	2390	4
370	0.05	880	3.2	1390	6.5	1890	4.4	2400	3.9
380	0.04	890	3.4	1400	6.6	1900	4.3	2410	3.9
390	0.05	900	3.6	1410	6.6	1910	4.3	2420	3.8
400	0.07	910	3.8	1420	6.6	1920	4.4	2430	3.7
410	0.08	920	4	1430	6.5	1930	4.4	2440	3.7
420	0.09	930	4.2	1440	6.5	1940	4.4	2450	3.7
430	0.09	940	4.4	1450	6.4	1950	4.4	2460	3.6
440	0.08	950	4.6	1460	6.3	1960	4.4	2470	3.6
450	0.08	960	4.8	1470	6.3	1970	4.4	2480	3.4
460	0.08	970	4.9	1480	6.2	1980	4.5	2490	3.4
470	0.08	980	5.1	1490	6.1	1990	4.4	2500	3.3
480	0.07	990	5.3	1500	6	2000	4.5	2600	3.6
490	0.06	1000	5.4	1510	5.9	2010	4.5	2700	3.3
500	0.06	1010	5.6	1520	5.8	2020	4.5	2800	5.1
510	0.06	1020	5.9	1530	5.8	2030	4.5	2900	5.4
520	0.07	1030	5.9	1540	5.7	2040	4.5	2940	5.4
530	0.07	1040	6	1550	5.6	2050	4.5	3000	4.8
540	0.07	1050	6.2	1560	5.6	2060	4.5	3100	4.8
550	0.06	1060	6.3	1570	5.5	2070	4.5	3200	4.8
560	0.06	1070	6.4	1580	5.4	2080	4.5	3300	5.7
570	0.06	1080	6.5	1590	5.3	2090	4.5	3600	4.2
580	0.07	1090	6.6	1600	5.3	2100	4.5	4000	6
590	0.08	1100	6.7	1610	5.2	2110	4.5	5000-25000	7.2
600	0.1	1110	6.7	1620	5.1	2120	4.5		
610	0.1	1120	6.9	1630	5	2130	4.5		
620	0.1	1130	6.9	1640	5	2140	4.5		
630	0.1	1140	7	1650	4.9	2150	4.5		
640	0.2	1150	7	1660	4.9	2160	4.5		
650	0.2	1160	7.1	1670	4.8	2170	4.5		
660	0.3	1170	7.1	1680	4.8	2180	4.4		
670	0.3	1180	7.1	1690	4.7	2190	4.4		
680	0.4	1190	7.2	1700	4.7	2200	3.9		
690	0.4	1200	7.2	1710	4.6	2210	3.2		
700	0.5	1210	7.2	1720	4.6	2220	3.4		

NOTE: OD values above are average values of representative lots of filter material. They are not gauranteed minimums for every lens. Minimum protection values will be specified on each product.

THE KENTEK CORPORATION

E-mail: info@kentek-laser.com http://www.kentek-laser.com

Safe operation of the laser when it is installed on the linac beamline is ensured by engineered controls. The collimation head is mounted close to a viewport. Once the laser beam passes through the vacuum

window all portions of the beam path are enclosed within the vacuum system. There are no other windows where light can get out. Also the laser beam in normal operation will be stopped by a graphite disk to eliminate reflections. The laser collimation head is mounted in a metal fixture which is attached to a 2.75" conflat viewport with set screws. The collimation head is mounted in a hole in this fixture with set screws. The optical path of the laser light can be broken by removing the fiber from the laser or by breaking the optical fiber path in one of two places. However the light directly from the optical fiber is highly divergent and poses no danger beyond a few millimeters from the fiber end. All fiber connections are optical SMA connectors which attach together with threads.

During alignment it will be necessary to bring beam outside of the confines of the vacuum pipe. In this case, a temporary laser controlled area will be established; barriers will be placed around the low energy beam line of the linac so that no person may inadvertently approach closer than 5.5 meters from the open beam line ports. In addition, signs will be placed at these barrier locations to alert passersby to this temporary set-up.

DEVELOP CONTROLS
IDENTIFY ES&H STANDARDS

Recognition, evaluation, and control of laser hazards are governed by the following documents.

American National Standards Institute (ANSI) Standard for Safe Use of Lasers;
(ANSI Z136.1-2000)

Laser Safety Subject Area

Brookhaven National Laboratory Environment Safety and Health Standard: 1.5.3 INTERLOCK SAFETY FOR PROTECTION OF PERSONNEL

ENGINEERING CONTROLS

☒ Beam Enclosures	☐ Protective Housing Interlocks	☐ Other
☐ Beam Stop or Attenuator	☒ Key Controls	
☐ Activation Warning System	☐ Other Interlocks	
☐ Ventilation	☐ Emission Delay	

Describe each of the controls in the space provided below this text. Interlocks and alarm systems must have a design review and must be operationally tested every six months. Controls incorporated by the laser manufacturer may be referenced in the manuals for these devices. **If any of the controls utilized in this installation requires a design review, a copy of the design review documentation and written testing protocol must be on file. Completed interlock testing checklists should be retained to document the testing history.**

Engineering Controls Description:

Safe operation of the laser during normal beam operations is ensured by engineered controls. The laser is a fully-enclosed unit containing pwer supply, controls, cooling and laser diode. Pins 1 and 2 on a 9-pin D connector have to be electrically connected for the laser to operate. During bench tests in the interlocked lab this conection is provided by the interlock system. During beamline operation an enable switch will be used to lock out the laser except when laser beam is expected and fully planned for. The light is transported over optical fiber to a laser-collimation head which is mounted on a fixture attached to the viewport. Once the laser beam passes through the vacuum window all portions of the beam path are enclosed within the vacuum system. There are no other windows where light can get out. Also the laser beam in normal operation will be stopped by a graphite disk to eliminate reflections. Removal of the laser-collimation head from the beam line requires a screwdriver.

The laser is enabled by a key. This key will be removed from the laser except when all described safety procedures are in place.

Durng operation on the linac beamline the laser light will be directed into a beamline chamber which has all viewports covered. Signs will be placed on these covers specifying that they are not to be removed.

ADMINISTRATIVE CONTROLS

☒ Laser Controlled Area ☒ Signs ☒ Labels ☐ Operating Limits

The format and wording of laser signs and labels are mandated by BNL and ANSI standards. Only the standard signs are acceptable. Standard signs are available from the BNL Laser Safety Officer.

All lasers must have a standard label indicating the system's wavelength, power, and ANSI hazard class. Required labels must remain legible and attached. The manufacturer should label commercial systems.

Standard Operating Procedures (SOPs) are required for laser system operation, maintenance (including alignment), and servicing. The SOPs need only contain the information necessary to perform these tasks and identify appropriate control measures including postings and personal protective equipment. The BNL Laser Safety Officer must approve SOPs and copies should be available at the laser installation for reference and field verification of stated control measures.

Administrative Controls Description:

When the installation is complete and the experiment is being conducted the optical paths of the laser will be fully enclosed and the barriers labeled.

Laser Controlled Area: During alignment the covers will be removed. Only lab personnel who are fully qualified to operate a class 4 laser will align the laser. During this phase it will be necessary to bring beam outside of the confines of the vacuum pipe. In this case, a temporary laser controlled area will be established; barriers will be placed around the low energy beam line of the linac so that no person may inadvertently approach closer than 5.5 meters from the open beam line ports.

Signs: Signs will be placed at these barrier locations to alert passersby to the temporary set-up during alignment.

For protection against the primary (980 nm) laser beam, laser eyewear with an optical density (OD) of at least 4.5 at this wavelength will be worn during alignment.

When the laser is operating during alignment, all individuals WILL put on protective laser eyewear as described above BEFORE the laser power supply is turned on.

As necessary the alignment procedure will be reviewed before alignment begins.

See Attachment 8.13 – CA-930-2 Guidance for Alignment/Maintenance Operations

CONFIGURATION CONTROL

A checklist must be developed for the purpose of verifying the placement and/or status of components that are used to mitigate hazards by configuration control. Examples include any protective housings, beam stops, beam enclosures, and any critical optics *(mirrors or lenses that could misdirect the beam and result in personnel hazard)*. Entries should also be included to ensure placement of required signs and labels and status of interlock verification. Completed checklists must be posted at the laser location. The checklist does not have to be redone unless there has been a system modification, extended shutdown, or change of operations.

See C-AD OPM 8.4o and C-AD OPM 8.4p

PERSONAL PROTECTIVE EQUIPMENT

☐ Skin Protection ☒ Eye Wear

Skin Protection: For UV lasers or lasers that may generate incidental UV in excess of maximum permissible exposure (MPE) describe the nature of the hazard and the steps that will be taken to protect against the hazard.

Eye Wear: All laser protective eyewear must be clearly labeled with the optical density and wavelength for which protection is afforded. Eyewear should be stored in a designated sanitary location. Color - coding or other distinctive identification of laser protective eyewear is recommended in multi-laser environments. Eyewear must be routinely checked for cleanliness and lens surface damage.

1. For invisible beams, eye protection against the full beam must be worn at all times unless the beam is fully enclosed.
2. For visible beams, eye protection against the full beam must be worn at all times during gross beam alignment.
3. Where hazardous diffuse reflections are possible, eye protection with an adequate Optical Density for diffuse reflections must be worn within the nominal hazard zone at all times.
4. If you need to operate the laser without wearing eye protection against all wavelengths present, explain the precautions that will be taken to prevent eye injury.

Define eyewear optical density requirements by calculation or manufacturer reference and list other factors considered for eyewear selection. The BNL Laser Safety Officer will assist with any required calculations.

EYE WEAR REQUIREMENTS

Laser System Hazard	Wavelength (nm)	Calculated Intra-beam Optical Density	Diffuse Optical Density*	NHZ** (meters)	Appropriate Eye Wear***
Diode	980	3.4 (10 sec)	NA	< 20 cm	Kentek SES-01-BW

* Diffuse ODs are calculated assuming a 600 second exposure, a viewing distance of 20 cm, perfect reflectivity, and viewing normal to the surface. The ODs required can decrease for more typical conditions in the laboratory.

**The Nominal Hazard Zone is that zone or distance inside which exists a hazard to the eye from a diffuse reflection (as well as direct or specularly reflected light) for the time specified, in this case, 600 seconds (10 minutes).

***Specified eyewear may not be the only possible option, but represents an approved choice; depending on other laser hazards present in the lab, other eyewear may be acceptable provided the optical densities are equivalent or greater than those required.

EYE WEAR SPECIFICATIONS		
Laser System Eyewear Identification	Wavelengths	Optical Density
Kentek SES-01-BW	980 nm	5.1

TRAINING

LASER SAFETY TRAINING

Laser Operators must complete sufficient training to assure that they can identify and control the risks presented by the laser systems they use. Owners/Operators and Qualified Laser Operators must complete the awareness level BNL World Wide Web based training course (TQ-LASER) every two years.

Qualified Laser Operators must also complete system-specific orientation with the system owner/operator. **System-specific training must be documented with a checklist that includes**

- Trainee name and signature
- Owner/Operator signature
- Date
- Brief list of topics covered e.g.
  - Review of SOPs;
  - Review of working procedures, and other program specific documentation.

All laser safety training must be repeated every two years.

See BTMS

Attachment 8.13 – CA-930-2 Guidance for Alignment/Maintenance Operations

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Procedural Considerations

1. To reduce accidental reflections, watches, rings, dangling badges, necklaces, reflective jewelry are taken off before any alignment activities begin. Use of non-reflective tools should be considered.
2. Access to the room/area is limited to authorized personnel only.
3. Consider having someone present to help with the alignment.
4. All equipment and materials needed are present prior to beginning the alignment
5. All unnecessary equipment, tools, combustible material (if fire is a possibility) have been removed to minimize the possibility of stray reflections and non-beam accidents.
6. Persons conducting the alignment have been authorized by the RI
7. A NOTICE sign is posted at entrances when temporary laser control areas are setup or unusual conditions warrant additional hazard information be available to personnel wishing to enter the area.

Alignment Methods to be used for this laser

1. There shall be no intentional intrabeam viewing with the eye. (This statement must remain. Do not delete.)
2. Co-axial low power lasers should be used when practical for alignment of the primary beam.
3. Reduce the beam power through the use of ND filters, beam splitters and dumps, or reducing power at the power supply. Avoid the use of high-power settings during alignment as much as is practical.
4. Laser Protective Eyewear shall be worn at all times during the alignment, within the parameters and notes established on the accompanying laser table.
5. Skin protection should be worn on the face, hands and arms when aligning at UV wavelengths.
6. Beam Control- the beam is enclosed as much as practical, the optics/optics mounts are secured to the table as much as practical, beam stops are secured to the table or optics mounts.
7. Areas where the beam leaves the horizontal plane shall be labeled.
8. Any stray or unused beams are terminated.
9. Invisible beams are viewed with IR/UV cards, business cards or card stock, craft paper, viewers, 3x5 cards, thermal fax paper, Polaroid film or similar technique. Operators are aware that specular reflections off some of these devices is possible, and that they may smoke or burn.

10. No intra-beam viewing is allowed unless specifically evaluated and approved by the LSO/DLSO. Intrabeam viewing is to be avoided by using cameras or fluorescent devices.
11. Normal laser hazard controls shall be restored when the alignment is completed. This includes enclosures, covers, beam blocks/barriers have been replaced, and affected interlocks checked for proper operation.

Beam alignment requires work with an open beam and involves directing the beam toward a series of reflective or partially reflective surfaces, such as mirrors or lenses, so that the beam follows some predetermined path. With respect to the laser, alignments may be internal or external.

Internal alignments are those occurring within the laser cavity or head and often place the worker at increased risk of electrical accidents as well as beam exposure. The need for internal alignments arises most often because of problems associated with beam mode or power.

External alignments are those that occur from the laser's end window to some terminal target. In between these two locations may be a number of optical components (optics) arrayed in more or less complex configurations. The need for external alignments occurs because of reconfiguration of the optical setup or replacement of components either within the laser head or in the open beam path. External alignments may be optical table (benchtop), laser-to-fiberport, fiberport-to-fiberport, free-space transmission, beam-to-sensor (receiver), and laser therapy. The following practices are most applicable to external alignments on the optical table.

General Considerations

1. **Co-Workers**: Consider performing alignments with a colleague or "buddy." Review alignment operating procedures with that person

2. **Prepare**: In advance, identify and obtain equipment and materials necessary to perform alignment.
    a. View beams indirectly: remote viewing, thermal paper, ceramic discs, IR/UV viewing scopes, paper business 3x5 inch cards, phosphor-viewing cards.
        i. Make sure viewing cards have diffusing surfaces.
        ii. Cover the face of cards with specular surfaces with clear, matte-finish tape.
        iii. If fluorescent viewing cards need optical charging, have a UV lamp on hand.
        iv. Make sure conversion wavelengths are visible through protective eyewear.
    b. Tools, targets, beam stops/blocks, power meter/detector, beam profiling system, curtain, signage, caution tape.

c. Make sure tools or items used in an around the beam path have non-reflective, diffusing surfaces at the wavelength(s) to be aligned.
d. Be aware of the Maximum Permissible Exposure levels for the type of laser you'll be working with.
e. Personal protective equipment (PPE): alignment eyewear, operational power eyewear, face shields for scattered UV, skin protection as necessary.

3. **Housekeeping**: Pay attention to housekeeping; make sure the immediate work area/benchtop/optical table is free from opportunistic specular reflectors that are not needed for alignment (glass bottles, razor blades, forceps, screw drivers, optical posts, photographic paper, plastic, dye cells, etc.)

4. **Sources of Reflection**: Remove jewelry from hands, wrist, ankles, ears, and neck that may be reflectors and are electrically conductive; if jewelry (e.g., wedding bands) is not easily removed, cover with multiple layers of electrical tape; remove tie tacks/clasps and neckties and materials in shirt pocket that may fall into the beam path.

5. **Posting**: A NOTICE sign is posted at entrances when temporary laser control areas are setup or unusual conditions warrant additional hazard information be available to personnel wishing to enter the area.

Alignment Methods to be used for this laser

1. Make sure that the beam shutter is closed or a beam block is in front of the end window. Make sure beam block is securely mounted.

2. Isolate and demarcate the area to avoid distractions and minimize the hazard to others.
   a. If Class-IV, open-beam system, make sure exterior warning signs/indicators are functioning, or posted if interlocks are not active.
   b. If embedded high-power laser, establish temporary laser controlled area.
      i. Restricted to authorized and trained individuals.
      ii. Use beam blocking barrier or laser curtain to contain beam
      iii. Cover windows or viewing ports that are within the controlled area.
      iv. Use "Notice" and "Danger" signs per ANSI Z136.1.
3. Confine the beam to the optical table or benchtop.

4. Prepare the beam delivery system: remove beam tubes or other parts of the protective housing as necessary, including extended sections that may be covered by beam tubes or bellows; check all optics (mirrors, lenses, filters, polarizers, expanders, etc.) and optomechanical components (base plates, post holders and fasteners, mirror mounts, etc.) ensuring they are currently aligned (for changes/additions to an existing alignment) and securely mounted.

5. If the beam path to be aligned is located in different rooms, locate a beam block in the beam path between the rooms, and align one room, then the other. If line of sight with

buddies in other rooms is blocked, use two-way, real-time communications. Be patient at each step.

6. Use the minimum beam power/energy for as many alignment steps as possible or use a low-power, coaxial laser for path simulation.
    a. For CW lasers with adjustable power, adjust the power to a minimum stable level.
    b.
    c. In some cases, power-reducing (e.g., neutral density) filters may be used during alignment.
    d. Ensure that you have protective eyewear with the appropriate value of optical density for the beam power; using high OD eyewear that is suitable for normal operation with low-power, alignment beams is a formula for failure as is wearing low OD, alignment eyewear for high-power beams.

7. Proceed with system alignment:
    a. Wear laser protective eyewear to view diffuse reflections from viewing devices.
    b. Never view laser beams directly unless the scenario has been specifically approved by a knowledgeable laser safety officer (LSO).
    c. Perform the “rough” or coarse” alignment with the beam blocked.
    d. As you progress down the optical path, place beam blocks behind optics to be adjusted to stop errant (stray) beams.
    e. When using viewing aids to visualize the beam, reach into the beam path slowly and deliberately with the card slightly angled so you can see the diffuse reflection. Adjust the optic so that the beam strikes the card just in front of the surface of the component.
    f. If the beam path changes elevation (+Z), be aware of the increased potential for vertical reflections.
    g. Close the shutter or insert the beam block during adjustments; re-secure optics making sure components are properly located/adjusted.
    h. Be aware of the potential for errant reflections (stray beams) from components such as polarizers and dielectric mirrors. Check for stray beams at each step and again after completing all alignment steps.
    i. If the alignment has been performed at lower power or with a low-power collinear beam but final steps will be performed at operational power levels, be sure and change to the appropriate eyewear for the high-power beam.
    j. Communicate with your co-worker at all times (e.g., during change of process step or before removal of protective eyewear.

8. Restore the system to normal operational mode (pay attention to the protective housing, interlock switches, and shutters) and verify normal operation.

C-AD OPM 8.4o – CA_930-2 Normal Configuration Checklist

☐ Vacuum system closed up.

☐ Laser cover secured.

☐ Barriers labeled.

☐ LEBT Beam Stops Closed or Linac secured.

Date _____

Name [print] _____

Signature _____

Life Number _____

C-AD OPM 8.4p – CA_930-2 Alignment Configuration Checklist

☐ Direct Beam Stop in place.

☐ Barriers around LEBT area in place.

☐ Warning signs in place.

Date _____

Name [print] _____

Signature _____

Life Number _____